Best Available Copy

(12) UK Patent Application (19) GB (11) 2 348 028 (13) A

(43) Date of Printing by UK Office 20.09.2000

(21) Application No 0014234.9

(22) Date of Filing 18.12.1998

(30) Priority Data
(31) 9801131 (32) 20.01.1998 (33) GB

(86) International Application Data
PCT/EP98/08524 En 18.12.1998

(87) International Publication Data
WO99/38318 En 29.07.1999

(51) INT CL$^7$
H04N 1/32

(52) UK CL (Edition R)
G4A AAP ACL
G5R RB265 RHB
H4F FBB

(56) Documents Cited by ISA
EP 0854633 A EP 0840513 A EP 0777197 A

(58) Field of Search by ISA
INT CL$^6$ H04N

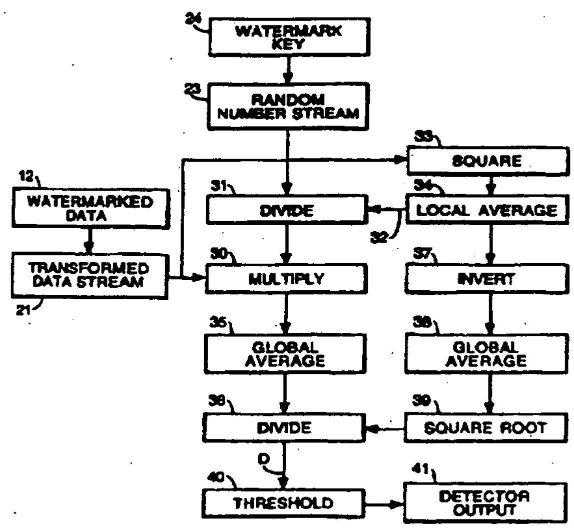
(71) Applicant(s)
Tandberg Television ASA
(Incorporated in Norway)
PO Box 322, Phillip Pedersens vei 20, 1326 Lysaker, Norway

(72) Inventor(s)
Robert Beattie
Antony Richard Huggett

(74) Agent and/or Address for Service
Gordon Drury
Tandberg Television Ltd, Intellectual Property Dept, Strategic Park, Comines Way, Hedge End, SOUTHAMPTON, Hampshire, SO30 4DA, United Kingdom

(54) Abstract Title
**Improvements in or relating to watermarks**

(57) The present invention relates to a method and apparatus for detecting the presence of a watermark in digital data. The digital data may represent picture or sound information and may be in the form of a broadcast television signal or a signal that has been recorded on a recording medium such as a compact disc. The watermark includes coefficients which have been subject to an inverse local orthogonal transform before being embedded in the input data. In order to detect the presence of the watermark, the input watermarked data is first forward transformed and subtracted from the watermark coefficients so as to derive the data coefficients. The data coefficients are squared and formed into a local average to obtain measure of the power in the local average. The watermark coefficients are divided by the local average so as to scale them and the scaled watermark coefficients are cross-correlated with the input data to detect whether the watermark is present. The cross-correlation is performed by means of a multiplier receiving the input data as a first input and the scaled watermark coefficients as a second input. The resulting output detection signal is subjected to a thresholding operation using a threshold set in dependence upon the global average power of the input data set.




GB 2 348 028 A

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H04N 1/32

A1

(11) International Publication Number: WO 99/38318

(43) International Publication Date: 29 July 1999 (29.07.99)

(21) International Application Number: PCT/EP98/08524

(22) International Filing Date: 18 December 1998 (18.12.98)

(30) Priority Data:
9801131.5 20 January 1998 (20.01.98) GB

(71) Applicant (*for all designated States except US*): NDS LIMITED [GB/GB]; 1 Heathrow Boulevard, 286 Bath Road, West Drayton, Middlesex UB7 0DQ (GB).

(72) Inventors; and
(75) Inventors/Applicants (*for US only*): BEATTIE, Robert [GB/GB]; 7A Shaftesbury Avenue, Portswood, Southampton, Hampshire SO17 1SB (GB). HUGGETT, Antony, Richard [GB/GB]; 205 Market Street, Eastleigh, Hampshire SO50 5PZ (GB).

(74) Common Representative: NDS LIMITED; Stoakes, Rosemarie, C., Gamma House, Enterprise Road, Chilworth, Hampshire SO16 7NS (GB).

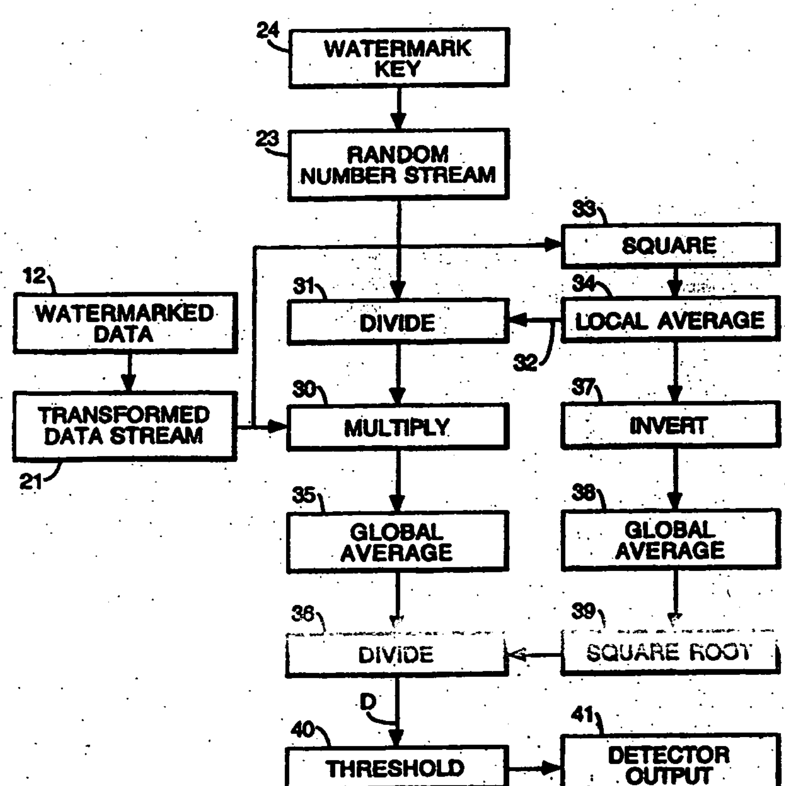
(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

**Published**
*With international search report.*
*Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.*

# (54) Title: IMPROVEMENTS IN OR RELATING TO WATERMARKS

**(57) Abstract**

The present invention relates to a method and apparatus for detecting the presence of a watermark in digital data. The digital data may represent picture or sound information and may be in the form of a broadcast television signal or a signal that has been recorded on a recording medium such as a compact disc. The watermark includes coefficients which have been subject to an inverse local orthogonal transform before being embedded in the input data. In order to detect the presence of the watermark, the input watermarked data is first forward transformed and subtracted from the watermark coefficients so as to derive the data coefficients. The data coefficients are squared and formed into a local average to obtain a measure of the power in the local average. The watermark coefficients are divided by the local average so as to scale them and the scaled watermark coefficients are cross-correlated with the input data to detect whether the watermark is present. The cross-correlation is performed by means of a multiplier receiving the input data as a first input and the scaled watermark coefficients as a second input. The resulting output detection signal is subjected to a thresholding operation using a threshold set in dependence upon the global average power of the input data set.



*FOR THE PURPOSES OF INFORMATION ONLY*

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

| | |
|---|---|
| AL | Albania |
| AM | Armenia |
| AT | Austria |
| AU | Australia |
| AZ | Azerbaijan |
| BA | Bosnia and Herzegovina |
| BB | Barbados |
| BE | Belgium |
| BF | Burkina Faso |
| BG | Bulgaria |
| BJ | Benin |
| BR | Brazil |
| BY | Belarus |
| CA | Canada |
| CF | Central African Republic |
| CG | Congo |
| CH | Switzerland |
| CI | Côte d'Ivoire |
| CM | Cameroon |
| CN | China |
| CU | Cuba |
| CZ | Czech Republic |
| DE | Germany |
| DK | Denmark |
| EE | Estonia |
| ES | Spain |
| FI | Finland |
| FR | France |
| GA | Gabon |
| GB | United Kingdom |
| GE | Georgia |
| GH | Ghana |
| GN | Guinea |
| GR | Greece |
| HU | Hungary |
| IE | Ireland |
| IL | Israel |
| IS | Iceland |
| IT | Italy |
| JP | Japan |
| KE | Kenya |
| KG | Kyrgyzstan |
| KP | Democratic People's Republic of Korea |
| KR | Republic of Korea |
| KZ | Kazakstan |
| LC | Saint Lucia |
| LI | Liechtenstein |
| LK | Sri Lanka |
| LR | Liberia |
| LS | Lesotho |
| LT | Lithuania |
| LU | Luxembourg |
| LV | Latvia |
| MC | Monaco |
| MD | Republic of Moldova |
| MG | Madagascar |
| MK | The former Yugoslav Republic of Macedonia |
| ML | Mali |
| MN | Mongolia |
| MR | Mauritania |
| MW | Malawi |
| MX | Mexico |
| NE | Niger |
| NL | Netherlands |
| NO | Norway |
| NZ | New Zealand |
| PL | Poland |
| PT | Portugal |
| RO | Romania |
| RU | Russian Federation |
| SD | Sudan |
| SE | Sweden |
| SG | Singapore |
| SI | Slovenia |
| SK | Slovakia |
| SN | Senegal |
| SZ | Swaziland |
| TD | Chad |
| TG | Togo |
| TJ | Tajikistan |
| TM | Turkmenistan |
| TR | Turkey |
| TT | Trinidad and Tobago |
| UA | Ukraine |
| UG | Uganda |
| US | United States of America |
| UZ | Uzbekistan |
| VN | Viet Nam |
| YU | Yugoslavia |
| ZW | Zimbabwe |

# IMPROVEMENTS IN OR RELATING TO WATERMARKS

The present invention relates to a method and apparatus for detecting a watermark. The invention has particular application to detecting a watermark in a digital picture or sound signal.

Watermarking is a well known technique which is used to protect against the fraudulent copying or counterfeiting of documents or currency. The physical medium carrying the document or currency is marked with a distinctive and recognisable mark which it is difficult to remove. In more recent times a need has arisen to protect digital signals representing picture information or audio information by means of a distinctive watermark. A watermark may be used to establish the true origin or ownership of the picture or audio information that is represented by the signals. It can be of particular benefit in the fields of digitally broadcast television signals and digitally recorded picture or sound signals.

The watermarking of documents or currency requires the watermark to be readily visible to assure the person examining the document or currency that the document or currency is genuine and has not been counterfeited. A physical technique of this sort is of course inapplicable to the protection of digital signals. Digital signals can be manipulated using digital techniques thus removing an existing watermark and possibly introducing a fresh watermark. The watermark for protecting a digital signal therefore should be obscured from an observer or listener of the information represented by the digital signal and should be difficult if not impossible to remove. The watermark should still be detectable by the originator of the watermark to determine if a signal is genuine.

In addition it is advantageous that the watermarking for digital signals be sufficiently robust so as to be capable of withstanding the compression and

decompression common in digital broadcasting techniques while still reliably indicating that the signal has been watermarked.

Existing watermarking schemes use a technique in which a watermark is generated from a random number sequence and added to the original picture or sound information to form a watermarked signal in which the watermark is obscured. When it is desired to detect the presence of the watermark, the watermarked signal is correlated with the watermark to generate a correlation signal which reveals the watermark.

A problem with the existing technique is that the watermark which is revealed through the correlation may be difficult to perceive. This may be due in part to the introduction of noise into the watermarked signal and may also be due to the difficulty in distinguishing the watermark from the information represented by the signal.

A need therefore exists to improve the correlation for detecting the watermark.

According to the present invention there is now provided a method of detecting the presence of a watermark in input digital data, the watermark including coefficients embedded in the data, the method comprising the steps of, transforming the data and applying the transformed data as a first input and the watermark coefficients as a second input to a cross correlator so as to generate an output detection signal, characterised in that the method further includes scaling the cross correlation by a predetermined characteristic of the data.

The invention has the advantage that the output detection signal is significantly less noisy than in a conventional detector.

Further according to the present invention, there is provided apparatus to detect the presence of a watermark in input digital data, the watermark including coefficients embedded in the input data, the apparatus comprising means to receive and transform the input data, a cross correlator having a first input to receive the transformed data and a second input to receive the watermark coefficients, the cross correlator being effective to generate an output detection signal, characterised in that scaling means are provided to scale the cross correlation by a predetermined characteristic of the data.

The invention will now be described , by way of example, with reference to the accompanying drawings in which;

Figure 1 shows a block diagram of a known apparatus for embedding a watermark into a signal to be protected by the watermark,

Figure 2 shows a block diagram of a known apparatus for detecting the presence of a watermark, and

Figure 3 shows details of apparatus according to the present invention for detecting the presence of a watermark in a watermarked signal input to the apparatus,

Figures 4 and 5 show a method of generating watermarked coefficients in a video signal which is subject to an inverse DCT transform,

Figure 6 shows a second apparatus according to the present invention for detecting the presence of a watermark in the watermarked coefficients of Figures 4 and 5,

Figure 7 shows the location of watermarked coefficients which have been subject to a forward DCT transform,

Figures 8 and 9 show two images of which one is original and unwatermarked and the other is watermarked,

Figure 10 is a graphical diagram of the correlation detected by the apparatus of Figure 2 including a conventional detector, and

Figure 11 is a graphical diagram of the correlation detected by the apparatus of Figure 6.

Figure 1 shows a source of unwatermarked data 10 which is intended to be combined with a watermark in a combining means 11 to generate watermarked data 12. The unwatermarked data 10 consists of a stream of digital data for example which represents picture or sound information and may constitute a video signal. The video signal may be a television broadcast signal or may be a video signal which is to be sent for recording on a recording medium such as a compact disc, laser disc, etc. In an alternative case, the unwatermarked data may be representative of sound information which is to be broadcast or to be recorded on a suitable recording medium such as a compact disc. The unwatermarked data is divided into a sequence of individual digital data sets or frames before being applied to the combining means 11. The watermark is applied to one or more of the digital data sets or frames. The watermark may be chosen to apply to a given succession of say five data sets or frames or may alternatively be applied to a known selection of individual data sets or frames.

The watermark consists of a series of watermark coefficients which are generated by means of a pseudo random number generator 13. The pseudo random number generator is a finite state machine which generates a long secure random sequence of numbers known only to the owner of the data. The pseudo random number generator 13 has an input to receive a watermark modulation key 14 which predetermines the initial state of the

number generator 13 and therefore the coefficients that are generated by the number generator 13.

The copyright information is embedded 13 by means of the embedding device 16 into the random number stream from the number generator 13. The copyright information may be a text legend or graphical information or other distinguishing information supplied from a copyright source 17. The embedded watermark coefficients are passed to a modulator 18 to be subjected to an inverse local orthogonal transform before being combined with the unwatermarked data in the combining means 11. The inverse transform may be chosen from a number of known such transforms including for example the inverse discrete cosine transform (DCT) which is well known in the field of compression of digital television signals. The purpose of the inverse transform is to spread the spectrum of the watermark . The result is to obscure the watermark when combined with the unwatermarked data.

The inverse transform applied to the watermark coefficients may be controlled by transform and analysis module 19 using the local data properties of the unwatermarked data. The data properties of the unwatermarked data are derived by a forward transform and analysis in the module 19.

It will be apparent to those skilled in the art that the source of copyright information may be omitted so that the watermark coefficients are applied directly from the number generator 13 to the modulator 18. Furthermore, the module 19 may be omitted so that the inverse transform applied to the watermark coefficients is not modified by the data properties of the unwatermarked data.

The inverse transform employed in the modulator 18 groups the random numbers appropriately to create the spectrum that is required. Low frequency terms are used in the inverse transformation because these withstand compression and decompression more robustly than higher frequency terms.

Turning now to Figure 2, there is shown a known method of detecting a watermark in the data that has been watermarked as described with reference to Figure 1. The watermarked data 12 is applied in the known detection apparatus as one input to a subtractor 20. The subtractor 20 receives the original unwatermarked data 21 as another input and generates an output consisting of the inverse transform of the watermark coefficients. A forward transform of the result from the subtractor 20 is performed by a forward transform generator 21. In the case where the inverse transform is an inverse DCT transform, the forward transform is the DCT transform. The result of the forward transform is applied as one input to a detector 22.

The detector 22 has another input from a pseudo random number generator 23 which is of the same form and construction as the generator 13 of Figure 1. The generator 23 receives a watermark modulation key 24 to correspond to the watermark modulation key 14 delivered to the generator 13. The detector 22 performs a cross correlation between the forward transform produced by the generator 21 with the coefficients generated by the generator 23 to produce an output detection signal 26. The output detection signal 26 may be taken as indicating the presence or absence of a watermark or may be interpreted to extract embedded copyright information.

Referring now to Figure 3, a method and apparatus embodying the invention is shown for detecting the presence of the watermark in the watermarked data 12. The watermarked data is first transformed by the forward transform generator 21 in the manner already described with reference to Figure 2. The transformed data 21 is applied as one input to a cross correlator including a multiplier 30 and a divider 31. The watermark coefficients are applied to another input to the detector by means of the pseudo random number generator 23. The generator 23 receives the watermark modulation key 24.

The transformed data coefficients are applied to a squarer 33 to form the square of the data coefficients from which the local average is formed in an averager 34. The result of the operations in the subtractor 32, the squarer 33 and the averager 34 is to compute a local average 32 of the power of the data coefficients. These operations may be represented by the following equation:

$$\overline{F}_i^2 = \frac{1}{N_i} \sum_{j \in K_i} (G_j)^2 \qquad (1)$$

where $\overline{F}_i^2$ is the local average power in K samples of the data sequence, $K_i$ is the set of neighbours used in the computation, $N_i$ is the number of members in the set, $G_j$ are the set of transformed data coefficients.

The divider 31, divides the watermark coefficients by a scaling factor. This scaling factor is determined by the local average 32 of the power of the data coefficients. The divider output is applied to the multiplier 30. The multiplier then cross correlates the transformed data 21 with the divided watermark coefficients. This produces a detected correlation signal for the set of neighbours used in computing the local average power. The detected correlation signal is then applied to a global averaging means 35 to form a global average of the correlation signal for all the samples in the data sequence that makes up the set of data 21. The global average is passed to a further divider 36.

The local average computed in the averaging means 34 is applied to an inverter 37 to produce a local average inverse signal. This local average inverse signal is applied to a global averager 38 to form the global average for the set of data 21 of the inverse signals from the inverter 37.

The global average from the averager 38 is subject to a square root operation in the square root means 39 and then applied as a second input to the divider 36. The division in the divider 36 forms a result which is a detection signal D which can be represented by the following equation

$$D = \frac{1}{\sqrt{B}} \sum_{i \in K} \frac{G_i W_i}{\overline{F}_i^2}, \quad B = \sum_{i \in K} \frac{1}{\overline{F}_i^2} \qquad (2)$$

The detection signal D is finally subject to a thresholding operation in the threshold circuit 40 to produce a detector output signal 41.

The detection threshold T is set in the threshold circuit 40 such that the probability of the detection signal D being greater than T when the watermark is not present gives an acceptable maximum false alarm possibility of P where P is given by the following equation;

$$P = \frac{1}{\sqrt{2\pi}} \int_T^{\infty} \exp\left\{-\frac{D^2}{2}\right\} dD \qquad (3)$$

It will be apparent from the block diagram of Figure 3 that the cross correlation occurring in the multiplier 30 is performed using the watermarked coefficients which have been scaled by the scaling factor 32. The process of dividing the watermark coefficients by the scaling factor 32 reduces considerably the level of the noise occluding the estimate of the watermark amplitude.

The scaling factor 32 may be applied to scale the input data instead of the watermark coefficients. This can be achieved by interposing the divider 31 between the transformed data stream 21 and the multiplier 30 instead of between the random number generator 23 and the multiplier 30. In yet another alternative, the scaling factor 32 can be used to scale the result of the cross correlation from the multiplier 30 instead of the watermark coefficients. In general, whichever alternative is chosen for the application of the scaling factor 32, the result is to effect a scaling of the cross correlation performed by the multiplier 30.

The detection signal D is derived in the divider 36 from the global average supplied by the averager 35 and the square root operation performed by the square root module 39. The detection signal D has a Gaussian distribution when no watermark is present. The Gaussian distribution is such that the probability that the signal D would exceed the threshold T can be made extremely remote. A high degree of assurance is thereby provided of the detection of the watermark when the detection signal D exceeds the threshold T.

The apparatus shown in Figure 3 may be applied to the detection of watermarks in video signals as will now be described with reference to Figures 4 to 11. The watermark coefficients are generated by first taking empty video frames and dividing each such frame into 16 x 16 small blocks. The number of blocks in each frame may be of a value other than 16 x 16 as will be apparent to those skilled in the art. Figure 4 shows in diagrammatic form an empty video frame 40 and four of the blocks into which it is divided. The first three blocks are numbered 1 to 3 and the last block is M.

Figure 5 shows one of the blocks in the frame 40. The block shown in Figure 5 is representative of each of the blocks in the frame 40 and as shown is itself divided into a number of locations. In the specific example described here, there are 4 x 4 locations in each block. Some of the locations in the block are populated with watermark coefficients $W_1$ to $W_5$. The chosen locations are distributed in the upper left hand portion of each block.

The inverse DCT of each block is taken to construct the actual watermark. It will be seen from Figure 5 that the population of watermark coefficients $W_1$ to $W_5$ correspond to the low frequency bases of the DCT transform and that the DC term is excluded. The process of constructing the inverse transform of the watermark coefficients is repeated for all the blocks of a frame so as to construct a complete watermark frame. The watermark frame is added to a video signal frame to produce a watermarked video frame. The same

process is repeated for all the video frames which it is desired to mark in a sequence of frames in a video signal.

The apparatus in Figure 6 is adapted to receive the frames of the video signal which have been watermarked as described with reference to Figures 4 and 5. The received video signal 60 is transformed by the forward transform generator 61. The forward transform generator divides each video frame into the same pattern of blocks as before (in the specific example 16 x 16 blocks) and takes the forward DCT transformation of each block. The result is to reverse the inverse transformation described with reference to Figures 4 and 5.

The unmarked video coefficients in each block are discarded resulting in the five marked coefficient locations $G_1$ to $G_5$ in each block as shown in Figure 7. The marked coefficients are supplied by the forward transform generator 61 as one input to the cross correlator comprising a multiplier 60a and a divider 61a. The 5 marked data coefficients in each block are presented as 5 neighbouring data samples.

It will be apparent to those skilled in the art that the number of data samples in each block is a matter of design choice and may be equal to a value other than 5. In general the number of data samples in each block presented to the cross correlator is K samples. The data samples presented by the forward transform generator 61 takes the form;

$$\{\{G_1^1 G_2^1..G_K^1\},\{G_1^2 G_2^2..G_K^2\},.....,\{G_1^M G_2^M..G_K^M\}\}$$

where $G_i^j$ is the ith sample from the block j. The total number N of the samples is $K * M = N$

The watermark coefficients are applied to another input to the detector of Figure 6 by means of the pseudo random number generator 23a which receives the watermark key 24a.

The watermark coefficients W from the generator 23a are ordered in the same manner as the transformed data coefficients and appear in the form;

$$\{\{W_1^1 W_2^1 .. W_K^1\},\{W_1^2 W_2^2 .. W_K^2\},....,\{W_1^M W_2^M .. W_K^M\}\}.$$

The marked data coefficients from the generator 61 are fed into the cross correlator of Figure 6 in synchronism with the generation of the watermark coefficients by the generator 23a. The marked data coefficients are supplied to a squarer 63 where they are squared before being supplied to an accumulator 64a. The end of each block of marked coefficients is detected by a detector 64b which latches the accumulator 64a to cause the accumulated value of the marked data coefficients to be passed to a multiplier 64c. The multiplier 64c multiplies the accumulated value by 1/N thereby to derive the local average 62 of the power of the marked data coefficients in each block.

The watermark coefficients from the generator 23a pass through a delay device 70 to the divider 61a. The delay device 70 imposes a delay on the incoming watermark coefficients to compensate for the delay in processing the marked data coefficients through the squarer 63 , the accumulator 64a and the multiplier 64c. The divider 61a thus receives the local average from the multiplier 64c in synchronism with the watermark coefficients from the delay device 70. The divider 61a scales the watermark coefficients of each block by the scaling quantity 62 which is the local average power for the marked data coefficients in the same block. The scaling quantity is clipped by a clip circuit 63C before application to the divider 61a. The watermark coefficients are scaled before application to the multiplier 60a to enhance the quality of the watermark amplitude estimate.

It will be apparent that the divider may be interposed betwen the data stream 61 and the multiplier 60a instead of between the delay device 70 and the multiplier 60a. In this case the scaling quantity 62 would be employed to scale the data stream 61 instead of the watermark coefficients. In yet another alternative, the scaling quantity 62 may be used to scale the output from the multiplier 60a.

The local average for each block generated by the multiplier 64c is applied to an inverter 67 to produce a local average inverse signal. The local average inverse signal from the inverter 67 is applied to an accumulator 68a which accumulates successive inverse local averages. The end of each video frame signal is detected by an end of frame detector 68b which supplies an end of frame signal to the accumulator 68a. The end of frame signal latches the accumulator 68a to pass the accumulated inverse local average values therein to a multiplier 68c. The multiplier multiplies the output from the accumulator 68a by 1/N thereby to derive a global average over each frame of the power of the marked data coefficients. A square root module 69 generates the square root of the global average from the multiplier 68.

The cross correlation performed by the multiplier 60a results in a cross correlation signal representing the correlation between the watermark coefficients and the marked data coefficients for each block in each frame of the video signal data. The cross correlation signals are passed to an accumulator 65a where the cross correlation signals are accumulated. The end of frame signal from the detector 68b latches the accumulator 65a and causes the accumulator to pass the accumulated cross correlation signals to a multiplier 65b. The multiplier multiplies the accumulated cross correlation signals by 1/N to derive a global average for each video frame.

The global average of the cross correlation signals is divided by the output from the square root module 69 to produce an output detection signal D. The

output detection signal D is subject to a thresholding operation by a threshold circuit 71 to produce a detector output signal 72.

Referring now to Figures 8 and 9 there are shown two samples of a video image. Figure 8 shows an original image which includes no watermarked coefficients. Figure 9 shows the same image but modified to include watermarked coefficients. Whilst the two images resemble one another so closely that the watermark is obscured to a viewer, it is necessary that the detector of the watermark should be able to discriminate between the two images with a high degree of assurance that one contains a known watermark whilst the other does not.

Figure 10 shows the response to be expected from a conventional detector. The detector output line 81 shows the detected correlation between the correct watermark coefficients and a watermarked video image such as that of Figure 9. The detector output line 82 shows the detected correlation between a set of incorrect watermark coefficients and the watermarked image. Two possible threshold levels 83 and 84 are shown in Figure 10 and it will be seen that the discrimination between a correct watermark and an incorrect watermark is relatively narrow. A threshold set at the level 84 would be unsatisfactory because there is the possibility of falsely detecting a watermark as shown where the line 82 exceeds the threshold 84. The threshold 83 is satisfactory but must be set carefully to avoid the possibility that the detector output line 81 does not drop below the threshold.

A feature of the detector output lines 81 and 82 in Figure 10 is that both deviate substantially from a median line. This is because of the relatively high noise levels associated with such a detector.

Turning now to Figure 11, there is shown the response from the detector of Figure 6. The line 91 shows the detected correlation between the correct watermark coefficients and the marked data coefficients of a video image

such as shown in Figure 9. The line 92 shows the detected correlation between incorrect watermark coefficients and the video image. Two possible threshold levels are shown at lines 93 and 94. It will be observed that the detector outputs represented by the lines 91 and 92 show a wide discrimination between a correct and an incorrect watermark. The output in each case is also subject to much less deviation than the corresponding output shown in Figure 10. As a consequence the threshold for the detection of a correct watermark can be set at a value which substantially removes uncertainty in detecting the watermark.

**CLAIMS**

1. A method of detecting the presence of a watermark in digital data, the watermark including coefficients embedded in the data, the method comprising the steps of, transforming the data and applying the transformed data as a first input and the watermark coefficients as a second input to a cross correlator so as to generate an output detection signal, characterised in that the method further includes scaling the cross correlation by a predetermined characteristic of the data.

2. A method as claimed in claim 1, wherein the step of scaling the cross correlation comprises scaling the watermark coefficients applied as the second input to the cross correlator.

3. A method as claimed in claim 1, wherein the step of scaling the cross correlation comprises scaling the transformed data applied as the first input to the cross correlator.

4. A method as claimed in claim 1, wherein the step of scaling the cross correlation comprises scaling the result of the cross correlation.

5. A method as claimed in claim 1, 2, 3 or 4, wherein the transformed data is applied to squaring means to form a local average of the power of the data within a global average encompassing the data, the local average being employed to scale the cross correlation.

6. A method as claimed in claim in claim 2, wherein the scaling of the cross correlation is performed by dividing the watermark coefficients by the local average.

7. A method as claimed in claim 6 wherein the transformed data is multiplied by the scaled watermark coefficients to cross correlate the data with the watermark coefficients.

8. A method as claimed in any one of the preceding claims, wherein the output detection signal is subjected to a thresholding operation.

9. A method as claimed in claim 8, wherein the thresholding operation is preceded by dividing the detection signal by a signal dependent on the global average of the power of the data.

10. A method as claimed in claim 9, wherein the detection signal is averaged before being divided.

11. Apparatus to detect the presence of a watermark in input digital data, the watermark including coefficients embedded in the input data, the apparatus comprising means to receive and transform the input data, a cross correlator having a first input to receive the transformed data and a second input to receive the watermark coefficients, the cross correlator being effective to generate an output detection signal, characterised in that scaling means are provided to scale the cross correlation by a predetermined characteristic of the data.

12. Apparatus as claimed in claim 11, wherein the scaling means is adapted to scale the cross correlation by scaling the watermark coefficients applied to the second input to the cross correlator.

13. Apparatus as claimed in claim 11, wherein the scaling means is adapted to scale the cross correlation by scaling the input data applied to the first input to the cross correlator.

14. Apparatus as claimed in claim 11, wherein the scaling means is adapted to scale the cross correlation by scaling the result of the cross correlation.

15. Apparatus as claimed in claim 11 further comprising a squarer to receive the transformed data and to form a local average of the power of the data within a global average encompassing the data, the scaling means being effective to employ the local average to scale the cross correlation.

16. Apparatus as claimed in claim 12, wherein the scaling means comprise a scaling divider to divide the watermark coefficients by the local average formed by the squarer.

17. Apparatus as claimed in any one of claims 11 to 16, wherein the cross correlator comprises a multiplier to multiply the scaled watermark coefficients with the transformed input data.

18. Apparatus as claimed in any one of claims 11 to 17, further comprising thresholding means to subject the output detection signal to a threshold.

19. Apparatus as claimed in claim 18, further comprising an output divider to divide the output detection signal by a signal dependent on the global average of the power of the data.

20. Apparatus as claimed in claim 19, further comprising an averager to average the output detection signal before it is divided by the output divider.

21. A method of detecting the presence of a watermark in input digital data, the method being substantially as hereinbefore described with reference to Figure 3 or Figure 6 of the accompanying drawings.

22. Apparatus for detecting the presence of a watermark in input digital data, the apparatus being substantially as hereinbefore described with reference to Figure 3 or Figure 6 of the accompanying drawings.

Fig.1.

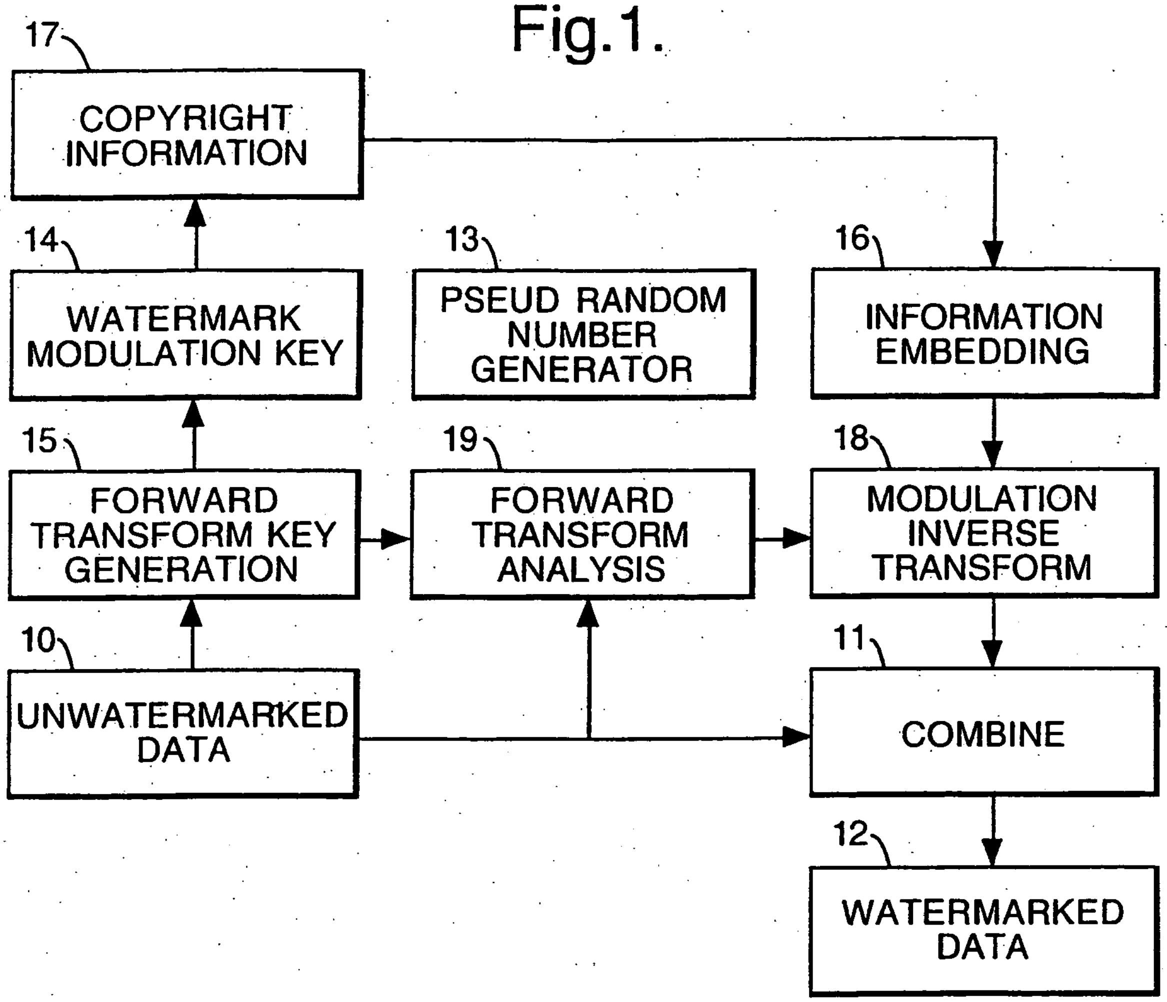



Fig.7.

| | | | |
|---|---|---|---|
| | $G_1$ | $G_3$ | |
| $G_2$ | $G_4$ | | |
| | | | |
| | | | |

Fig.2.

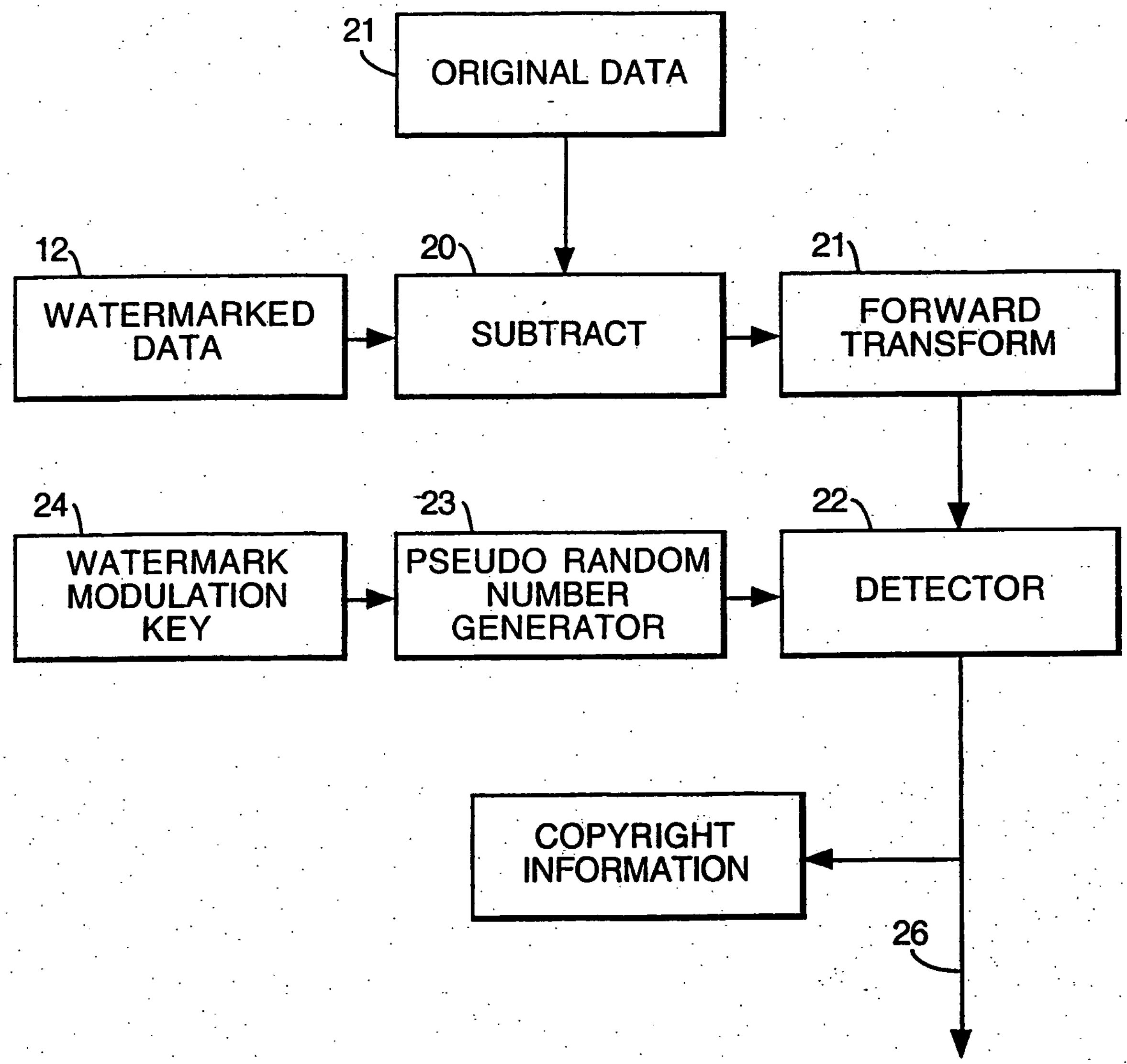

21
ORIGINAL DATA
12
WATERMARKED DATA
20
SUBTRACT
21
FORWARD TRANSFORM
24
WATERMARK MODULATION KEY
23
PSEUDO RANDOM NUMBER GENERATOR
22
DETECTOR
COPYRIGHT INFORMATION
26

Fig.3.

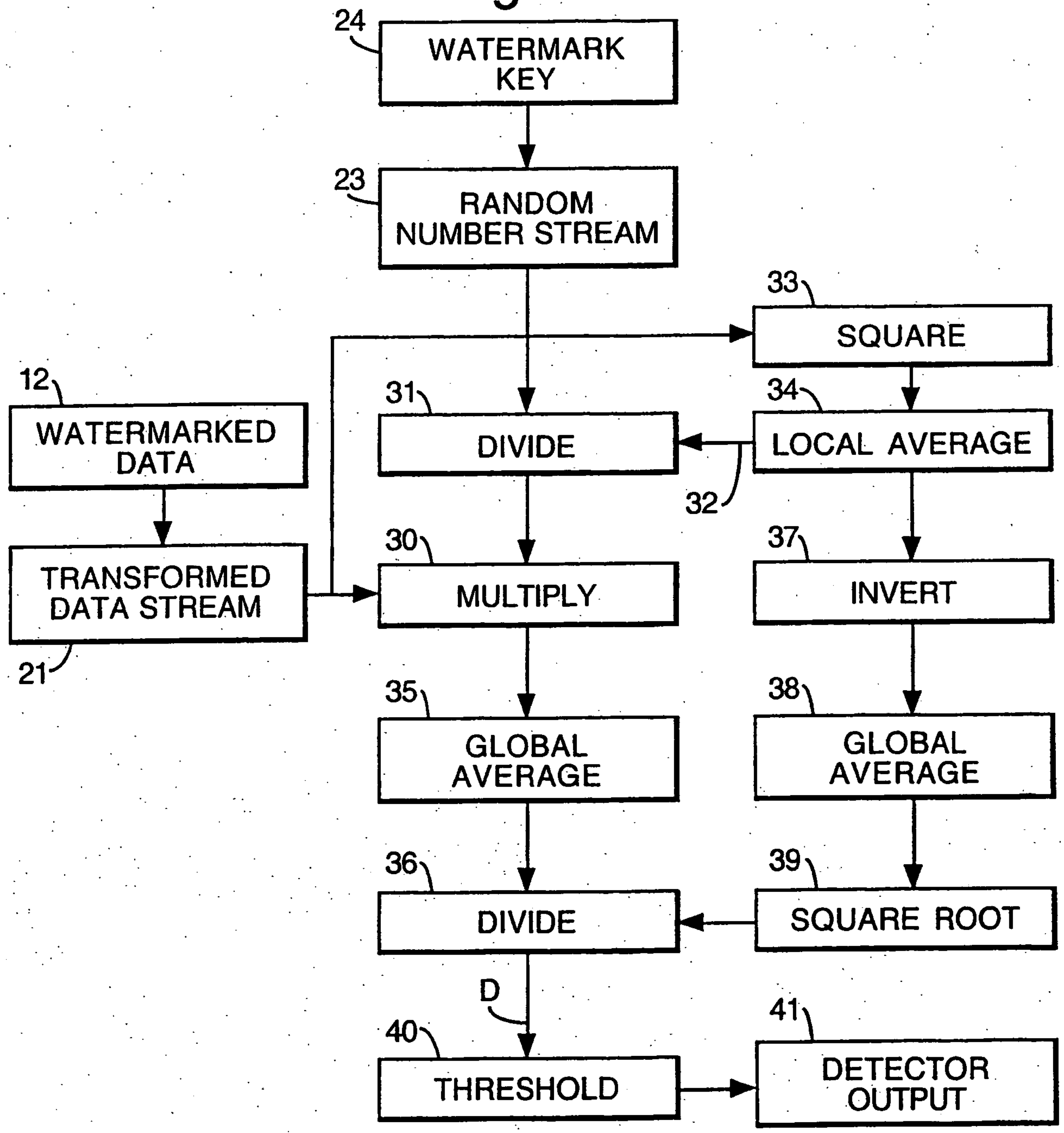

24
WATERMARK KEY
23
RANDOM NUMBER STREAM
33
SQUARE
34
LOCAL AVERAGE
12
WATERMARKED DATA
31
DIVIDE
32
30
MULTIPLY
37
INVERT
TRANSFORMED DATA STREAM
21
35
GLOBAL AVERAGE
38
GLOBAL AVERAGE
36
DIVIDE
39
SQUARE ROOT
D
40
THRESHOLD
41
DETECTOR OUTPUT

Fig.4.

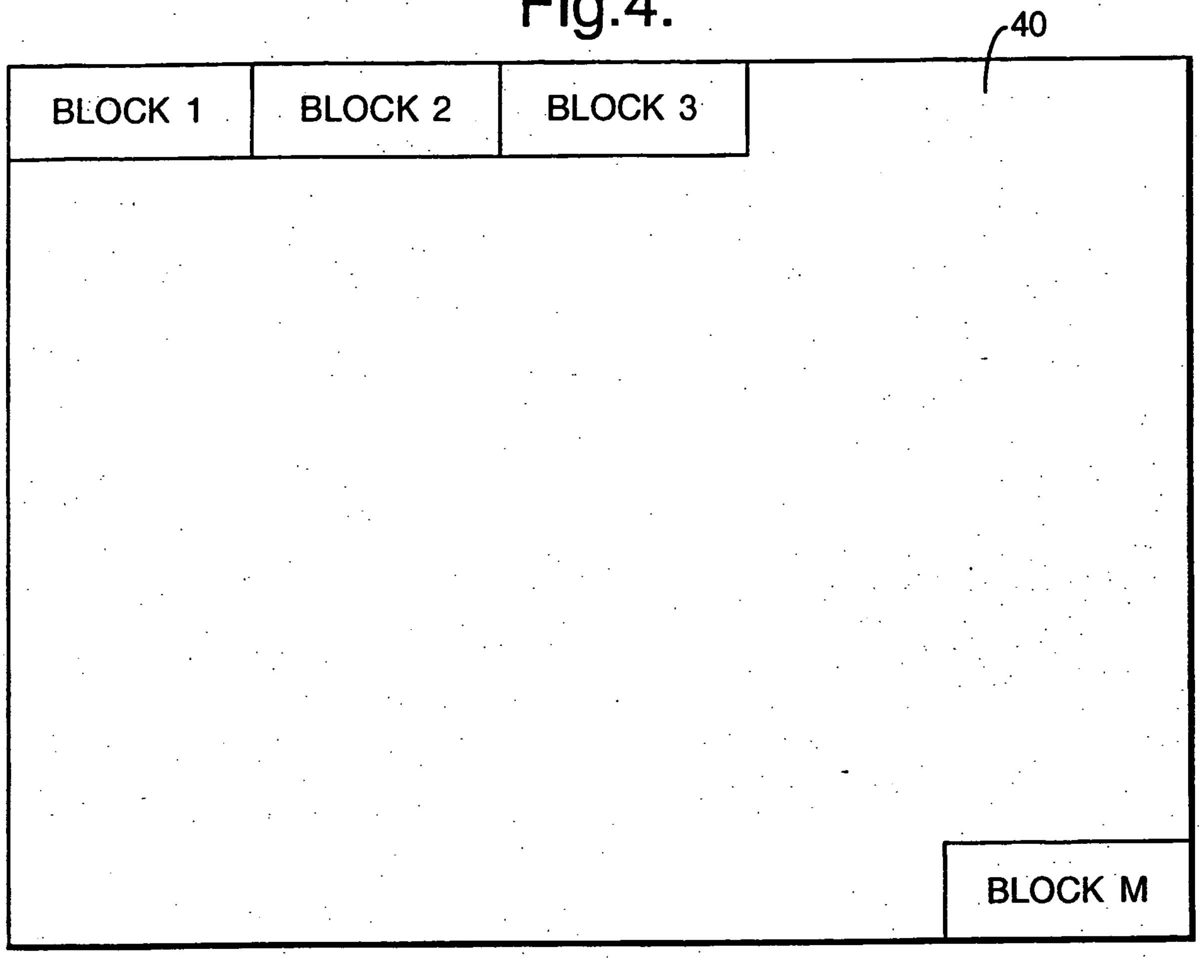



Fig.5.

| | | | |
|---|---|---|---|
| | $W_1$ | $W_3$ | |
| $W_2$ | $W_4$ | | |
| $W_5$ | | | |
| | | | |

Fig.6.

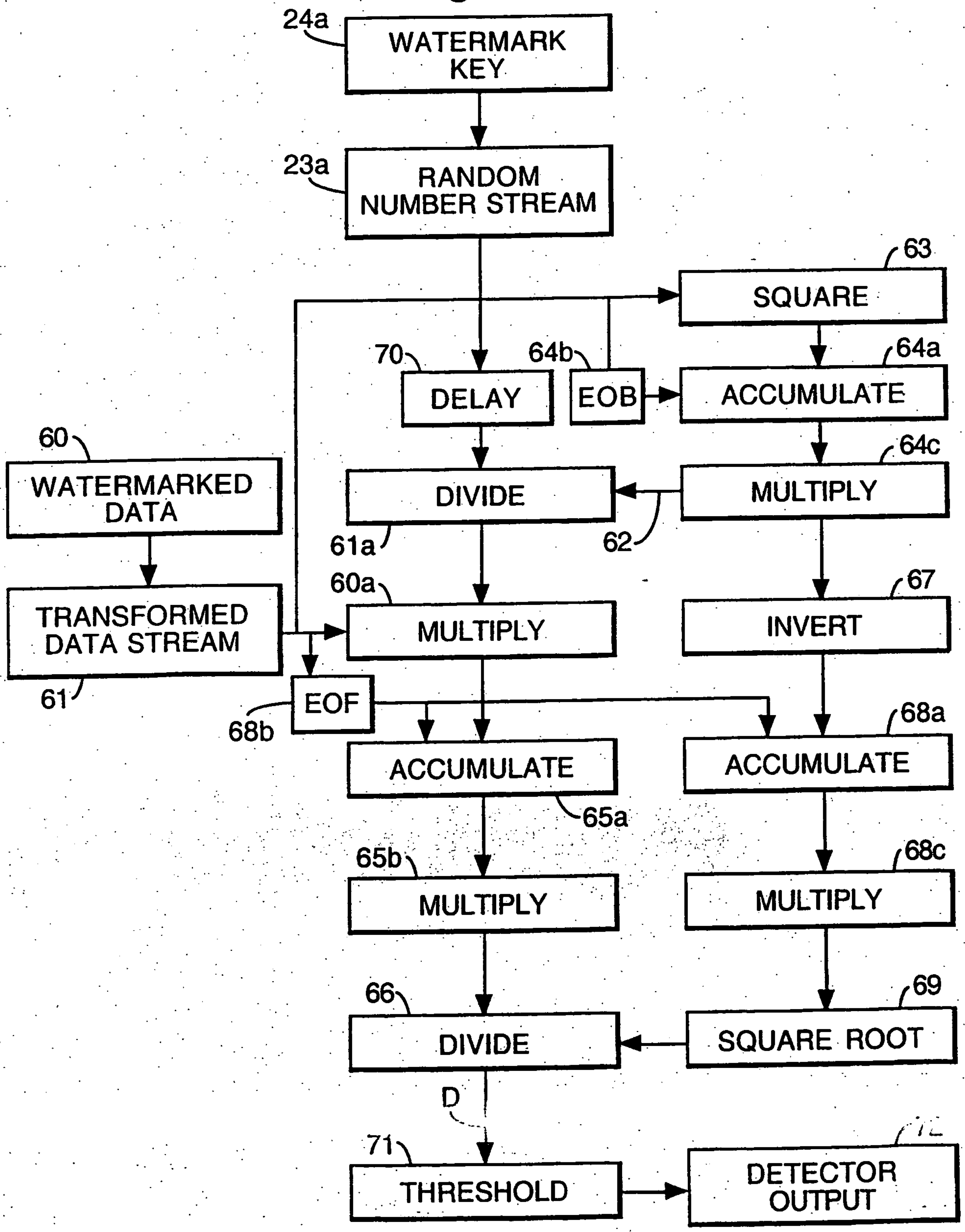

24a
WATERMARK KEY
23a
RANDOM NUMBER STREAM
63
SQUARE
70
DELAY
64b
EOB
64a
ACCUMULATE
60
WATERMARKED DATA
DIVIDE
64c
MULTIPLY
61a
62
60a
TRANSFORMED DATA STREAM
MULTIPLY
67
INVERT
61
EOF
68b
68a
ACCUMULATE
ACCUMULATE
65a
65b
MULTIPLY
68c
MULTIPLY
66
DIVIDE
69
SQUARE ROOT
D
71
THRESHOLD
DETECTOR OUTPUT

Fig.8.

ORIGINAL IMAGE

Fig.9.

WATERMARKED IMAGE

Fig.10.

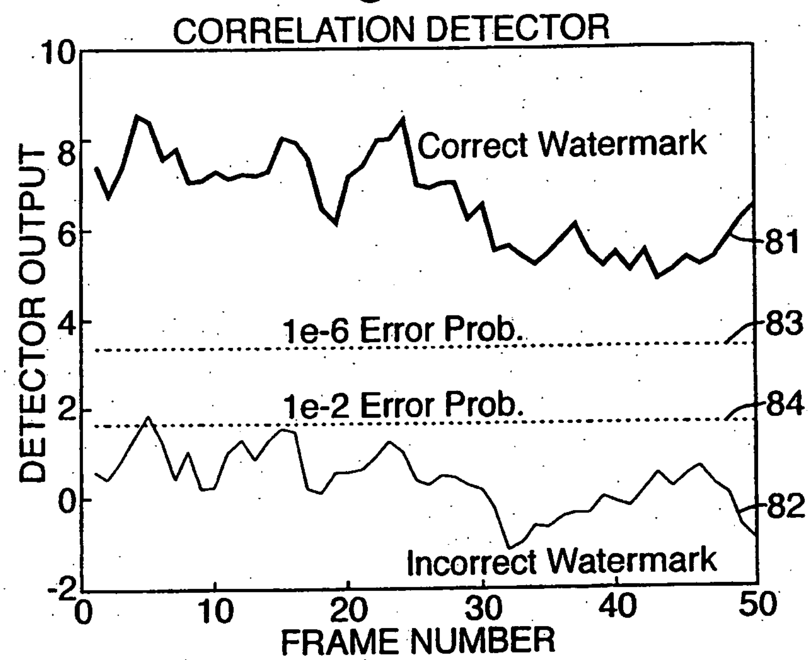
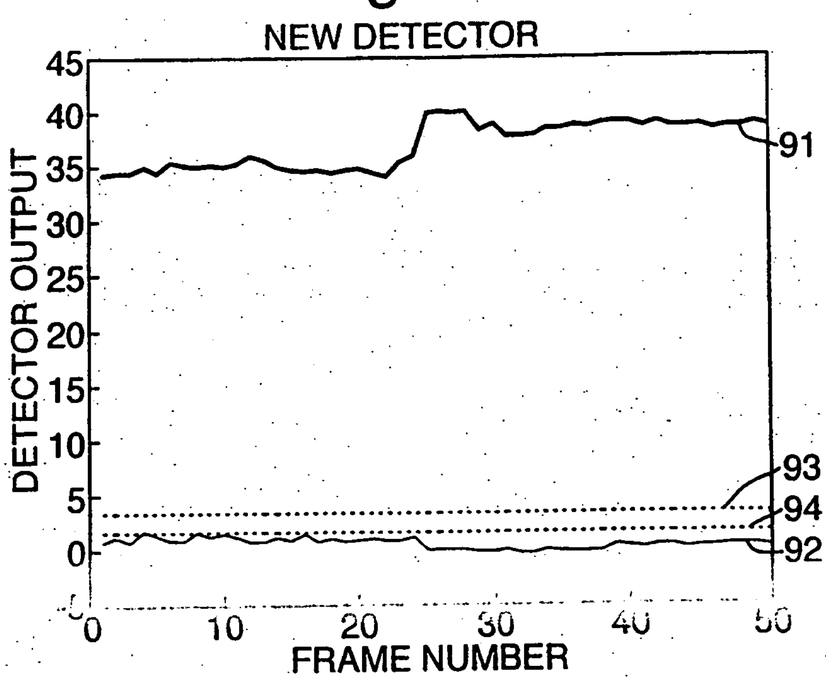

CORRELATION DETECTOR
DETECTOR OUTPUT
10
8
6
4
2
0
-2
Correct Watermark
1e-6 Error Prob.
1e-2 Error Prob.
Incorrect Watermark
81
83
84
82
0
10
20
30
40
50
FRAME NUMBER

Fig.11.


NEW DETECTOR
DETECTOR OUTPUT
45
40
35
30
25
20
15
10
5
0
91
93
94
92
0
10
20
30
40
50
FRAME NUMBER

# INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 98/08524

**A. CLASSIFICATION OF SUBJECT MATTER**
IPC 6 H04N1/32

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| P,X | EP 0 854 633 A (NIPPON ELECTRIC CO) 22 July 1998<br>see column 7, line 28 - column 8, line 1 | 1,2,5,6, 13,14, 17,18 |
| P,X | EP 0 840 513 A (NIPPON ELECTRIC CO) 6 May 1998<br>see column 7, line 3 - column 8, line 36<br>see column 11, line 10 - column 12, line 4 | 1,2,5,6, 13,14, 17,18 |
| A | EP 0 777 197 A (EASTMAN KODAK CO) 4 June 1997<br>see abstract | 1,13 |

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 25 May 1999 | 01/06/1999 |

| Name and mailing address of the ISA | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,<br>Fax: (+31-70) 340-3016 | HAZEL, J |

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/EP 98/08524

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
| --- | --- | --- | --- |
| EP 0854633 A | 22-07-1998 | CA 2226719 A | 17-07-1998 |
| | | JP 10290312 A | 27-10-1998 |
| EP 0840513 A | 06-05-1998 | AU 4434097 A | 07-05-1998 |
| | | CA 2219205 A | 05-05-1998 |
| | | JP 10145757 A | 29-05-1998 |
| EP 0777197 A | 04-06-1997 | US 5859920 A | 12-01-1999 |
| | | JP 9191395 A | 22-07-1997 |